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PATENT APPLICATION

TITLE:

**SUBSTRATES FOR POWDER DEPOSITION
CONTAINING CONDUCTIVE DOMAINS**

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SUBSTRATES FOR POWDER DEPOSITION CONTAINING CONDUCTIVE DOMAINS

The present invention relates to substrates used as the support on which powders
5 are deposited using techniques wherein electrical forces attract the powders for localized deposition.

The applicants or those working with applicants have previously described
apparatuses and techniques for using electrical forces to make controlled depositions of
materials. Such depositions make it possible to deposit controlled amounts of, for
10 example, a pharmaceutical onto spatially resolved areas of a substrate. These techniques
have typically deposited charged particles or grains onto a substrate mounted on a device
("electrostatic chuck") that provides the electrical forces (e.g., electrostatic) that attracts
the particles or grains. The particles or grains are typically charged, though attraction
can occur through induced polarizations of the particles or grains. The electrostatic
15 chuck has, for example, electrode pads to which electrical potentials are applied to create
attractive forces. Adjacent electrodes, of a different potential, can be used to shape the
attractive forces or steer particles or grains away from undesired locations. One such
electrostatic chuck is illustrated in **Figure 3**. Once attracted to a given location, grains or
particles can induce an image force through their proximity to conductors, which image
20 force can be a powerful contributor to the forces retaining the grains or particles. Other
retentive forces include other charge and charge redistribution induced forces, packing
forces and Van der Waals forces.

A limitation on this technology has been the amount of particles or grains that
can be effectively directed to a given location. One source of this limitation is a practical
25 limit to the strength and localization of the electrical forces close to a given deposition
location. The present invention addresses this problem by creating substrates for the
deposition having patterned inlays of conductive material, which conductive inlay
material serves as an extension or adjunct to the electrode pads of the electrostatic chuck,
allowing greater charge density near the site of deposition. The invention provides
30 improved quality of the depositions and allows larger quantities to be deposited.

Summary of the Invention

The invention provides, for example, a conductive inlay film comprising: a layer of dielectric film having a pattern of holes suitable to define selected regions to which particles will be deposited by electrostatic deposition; and a conductive element comprising polymer, which element comprises (a) a conductive film laminated against the dielectric film or (b) a conductive film embedded within the holes, the portion of the conductive element appearing within the holes comprising conductive inlays, wherein the conductive element is adapted to contact one or more electrode pads and provide electrical potentials at the selected regions, and wherein the dielectric film electrically isolates the selected regions. The invention can be used to deposit measured amounts of particles on the selected regions of substrates, wherein the amounts of particles deposited on the selected regions can be measured amounts. The measured amounts can be of a medicament, forming a dosage unit. Or, for example, the conductive inlay film can comprise a diagnostic product with measured amounts of diagnostic reagent at two or more selected regions.

The invention also provides a method of electro-attractive deposition onto a substrate comprising: layering a conductive inlay film onto a surface of an electrostatic chuck comprising at least one electrode contacting the surface, wherein the conductive inlay film comprises conductive polymer effective to transmit potentials from the electrodes to the vicinity of selected regions of the conductive inlay film and dielectric film effective to electrically isolate the selected regions; applying a potential to the at least one electrode; directing particles toward the conductive inlay film; and selectively depositing particles at the selected regions. Note that the term "electrostatic chuck" indicates its use to attract charged powder/particles; such a chuck need not necessarily electrically adhere the substrate to which the powder/particles will be applied. The substrate can be layered on the chuck with, for example, vacuum or adhesive.

Further provided is a pharmaceutical, vitamin formulation, sweetener formulation, herbal formulation, veterinary formulation, or diagnostic product comprising: at least a portion of a conductive inlay film, the conductive inlay film comprising: a layer of dielectric film having a pattern of holes suitable to define selected regions to which particles will be deposited by electrostatic deposition; and a conductive element comprising polymer, which element comprises (a) a conductive film laminated against the dielectric film or (b) a conductive film embedded within the holes, the portion

of the conductive element appearing within the holes comprising conductive inlays), the portion comprising a said inlay surrounded by the dielectric film; and a defined amount of pharmaceutical, vitamin, sweetener, herbal product, veterinary pharmaceutical or diagnostic agent selectively deposited on one or more said inlays.

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Brief Description of the Drawings

Figures 1A and 1B display a conductive inlay film according to the invention.

Figures 2A and 2B show another a conductive inlay film according to the invention.

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Figure 3 shows an exemplary electrostatic chuck.

Detailed Description of the Invention

One illustrative embodiment of the invention is shown in **Figure 1**. **Figure 1A** shows a cross-section of conductive inlay film **20** having conductive film **22** laminated to dielectric film **21**. The dielectric film **21** is of a relatively low conductivity and thickness as to allow selective attraction of charged particles to selected regions **23**, while limiting any attraction of the particles to areas outside the selected region **23**.

Suitable dielectric films include, for example, films of ethylcellulose, cellulose acetate phthalate, hydroxypropylmethyl cellulose (HPMC), hydroxypropylmethyl cellulose phthalate, hydroxypropyl cellulose (HPC), methyl cellulose, modified starch, protein (including, e.g. crosslinked gelatin), alginic acid, acrylic polymer (e.g., methyl methacrylate, ethyl acrylate, copolymers of methyl methacrylate, and ethyl acrylate, and the like, such as EudragitTM acrylic copolymers), polyalkylene oxide (such as polyethylene oxide), polyvinyl alcohol, polyvinylpyrrolidone (PVP), crosslinked PVP, polylactide, poly(lactide-co-glycolide), non-woven fabric, paper, and the like. Film forming processes include casting of polymer solutions or dispersions and extrusion molding of polymer powders.

The conductive film is preferably formed of materials that are appropriate for human consumption. For certain materials, this preferred restriction means appropriate in the amount and dosing of the consumable product. Preferably, the conductive film is formed of a polymer which is itself conductive, or which provides a structural framework for a conductive material incorporated into the film. The conductive material can be, for example, a metallic weave, metal particles (such as particles of gold, silver or

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iron), carbon black particles, particles of other ionic species, and the like. The conductive material can also be a conductive polymer, such as gelatin or other proteinaceous material. Suitable polymers for imbedding conductive material include ethylcellulose, cellulose acetate phthalate, HPMC, hydroxypropylmethyl cellulose phthalate, HPC, methyl cellulose, modified starch, protein (including, e.g. crosslinked gelatin), alginic acid, acrylic polymer (e.g., methyl methacrylate, ethyl acrylate, copolymers of methyl methacrylate, and ethyl acrylate, and the like, such as EudragitTM acrylic copolymers), polyalkylene oxide (such as polyethylene oxide), polyvinyl alcohol, PVP, crosslinked PVP, polylactide, poly(lactide-co-glycolide), non-woven fabric, paper, and the like. The water soluble polymer examples can be cast from a water solution, with the casting and drying conducted at a temperature above the lower critical solution temperature ("LCST"). The LCST for HPC, for example, is typically in the 50-55°C range. Film forming processes again can include casting of polymer solutions or dispersions and extrusion molding of polymer powders.

Preferably, the conductive elements of the conductive inlay film, e.g., conductive film **22** or conductive inlay **32** (see below), have a resistivity of 10^5 ohm/square or less, more preferably 10^4 or 10^3 ohm/square or less.

The selected regions **23** can be formed, for example, by cutting the dielectric film prior to laminating the film to the conductive film. The sizes of the selected regions **23** are, in pharmaceutical applications especially, for example from 1 mm to 10 mm in width or diameter.

The conductive inlay film of the invention is preferably flexible. The elements of the conductive inlay film on which particles are deposited are favorably water-swellaable or dispersible, facilitating the dispersal or dissolution of deposited particles (see definition below) in appropriate aqueous solutions (e.g., acidic, basic or neutral, depending on the intended use of the conductive inlay film with deposited particles). Suitable thicknesses for the conductive inlay film include from 0.5 mil to 10 mil, more preferably 1.0 mil to 5 mil.

Another illustrative embodiment of the invention is shown in **Figure 2**. **Figure 2A** shows a cross-section of conductive inlay film **30** having conductive inlays **32** in dielectric film **31**. The dielectric film **31** is of a relatively low conductivity and thickness as to allow selective attraction of charged particles to selected regions **33**, while limiting

any attraction of the particles to areas outside the selected region 33. This embodiment can be designed so that the conductive inlays 32 align with conductive pads on the surface of an electrostatic chuck. Again, the dielectric film is selected to maintain the electrical isolation of the selected regions such that particle-attracting fields are confined to these regions.

The embodiment of **Figure 2** can be formed, for example, by layering the dielectric film, on which holes corresponding to the selected regions have been formed, onto a release layer. A polymer solution or water-swellable gel, which can have conductive particles suspended therein, is used to fill the holes. Water-swellable gels-forming polymers include ethylcellulose, cellulose acetate phthalate, HPMC, hydroxypropylmethyl cellulose phthalate, HPC, methyl cellulose, modified starch, protein (including, e.g. crosslinked gelatin), alginic acid, acrylic polymer (e.g., methyl methacrylate, ethyl acrylate, copolymers of methyl methacrylate, and ethyl acrylate, and the like, such as EudragitTM acrylic copolymers), polyalkylene oxide (such as polyethylene oxide), polyvinyl alcohol, PVP, crosslinked PVP, polylactide, poly(lactide-co-glycolide), non-woven fabric, paper, and the like. The solution, or the water-swelled gel are embedded in the dielectric film by, for example, drying in a humidity and temperature controlled chamber. The conductive inlay film so formed can now be peeled off the release layer.

It will be recognized that the embodiment of **Figure 2** can be laminated against a conductive film to form an embodiment that is a hybrid of the embodiments of **Figure 1** and **Figure 2**.

It will be understood that the conductive inlay films of the invention can be used in methods of electrostatically depositing particles thereon. The use of electrostatic chucks for conducting such depositions, including methods of charging the particles (e.g., by induction or tribocharging) and measuring deposition amounts, are described in a number of patents and patent applications identified below. Deposition measurements can include optical measurement following deposition, and the use of electrical sensors that dynamically monitor deposition. One useful method of charging the particles is induction charging by passing the particles through a jet mill with conductive walls to which a potential is applied.

Figure 3 shows a cross-section of a coplanar chuck 10 where deposition electrodes 14 are separated from shield electrodes 13 by dielectric (preferably

atmosphere) **15**, with these features seated in base material **12**. The deposition electrodes **14** are preferably formed of series 300 stainless steel. Deposition electrodes **14** contain a pin receptacle **16** for connection to circuit board **11**. Base material **12** is made of a dielectric such as Noryl® polymer (GE Plastics, Pittsfield, MA). Noryl engineered plastics are modified polyphenylene oxide, or polyphenylene oxide and polyphenylene ether, resins. The modification of these resins involves blending with a second polymer such as polystyrene or polystyrene/butadiene. By varying the blend ratio and other additives, a variety of grades are produced. Unmodified, these polymers are characterized by regular closely spaced ring structures (phenyl groups) in the main molecular chain. This feature along with strong intermolecular attraction causes extreme stiffness and lack of mobility. The shield electrodes **13** can be made from a conductive material (such as 300 series stainless steel) adhered to the base material **12**, for example by an adhesive or a double-sided, rubber-based adhesive tape. The annular gaps that are the preferred embodiment of dielectric **15** can be made by drilling a series of holes in the conductor layer that will form the shield electrodes **13**. The deposition electrodes **14** can be, for example, pressed or glued into the base material. The assembly is preferably ground to create a flat, coplanar surface, for example within a tolerance of 0.0002 inches. Where dielectric **15** is atmosphere (that atmosphere in which the electrostatic chuck operates), preferably the portion of the dielectric separation of the electrodes comprising atmosphere is sufficient so that in use the upper plane of the electrostatic chuck aligned with dielectric **15** discharges completely between depositions. Such an amount of dielectric separation is “substantial” separation.

Such an electrostatic chuck can be simply modified with the techniques described to incorporate electrically isolated shield electrodes that can be separately connected to control electronics to provide the sensing circuits described above. Dimension **A** can be, for example, 0.01 inch; Dimension **B** can be, for example, 0.157 inch; Dimension **C** can be, for example, 0.236 inch; Dimension **D**, the pitch between pixels, can be, for example, 0.3543 inch. The electrostatic chuck can be operated, for example, with a voltage of ~700 or ~1,400 V applied to the deposition electrodes.

The measured amounts of particles or grains deposited by the invention can be useful in a number of contexts, such as pharmaceuticals, vitamin formulations, sweetener

formulations, herbal formulations, veterinary formulations, diagnostic products (with defined quantities of control substances or diagnostic reagents), and the like.

GLOSSARY

The following definitions are provided to facilitate understanding of certain terms used frequently herein:

“**Particles**” for deposition are, for the purposes of this application, aggregates of molecules, typically of at least about 3 nm average diameter, such at least about 500 nm or 800 nm average diameter, and are preferably from about 100 nm to about 5 mm, for example, about 100 nm to about 500 μ m. Particles are, for example, particles of a micronized powder, or polymer structure that can be referred to as “beads.” Beads can be coated, have adsorbed molecules, have entrapped molecules, or otherwise carry other substances.

“**Electro-attractive dry deposition**” refers to methods that use electrical forces to attract or deposit charged particles to a surface.

“**Dosage unit**” refers to a convenient amount of a given substance. For pharmaceuticals, the term typically refers to amounts that add up to, using a convenient number of dosage units, an appropriate dosage of a pharmaceutical.

The invention described herein can be used in conjunction with a number of devices and methods described by applicants or those working with applicants. For example, the “Electrostatic Sensing Chuck Using Area Matched Electrodes” application of Sun et al., Serial No. 09/417,736, filed October 14, 1999, and the “Device for the Dispersal and Charging of Fluidized Powder” application of Sun et al., Serial No. 09/417,820, October 14, 1999 can be used in conjunction with the invention. Other devices or methods that can be used with various aspects of the present invention include, for example, the methods for use of transporter chucks, acoustic bead dispensers and other powder-manipulating devices set forth in Sun, “Chucks and Methods for Positioning Multiple Objects on a Substrate,” US Patent No. 5,788,814, issued August 4, 1998; Sun et al., “Electrostatic Chucks and a Particle Deposition Apparatus Therefor,” US Patent No. 5,858,099, issued January 12, 1999; Pletcher et al., “Apparatus for Electrostatically Depositing a Medicament Powder Upon Predefined Regions of a Substrate,” US Patent No. 5,714,007, issued February 3, 1998 (see, also US Patent No. 6,007,630, issued December 28, 1999); Sun et al., “Method of Making Pharmaceutical

Using Electrostatic Chuck," US Patent No. 5,846,595, issued December 8, 1998; Sun et al., "Acoustic Dispenser," US Patent No. 5,753,302, issued May 19, 1998; Sun, "Bead Transporter Chucks Using Repulsive Field Guidance," US Patent 6,098,368, issued 1-Aug-2000; Sun, "Bead Manipulating Chucks with Bead Size Selector," US Patent No. 5,988,432, issued November 23, 1999; Sun, "Focused Acoustic Bead Charger/Dispenser for Bead Manipulating Chucks," US Patent 6,168,666, issued 2-Jan-2001; Sun et al., "AC Waveforms Biasing For Bead Manipulating Chucks," US Patent 6,149,774, issued 21-Nov-2000.; Sun et al, "Apparatus for Clamping a Planar Substrate," Serial No. 09/095,321, filed 10 June 1998; Poliniak et al., "Dry Powder Deposition Apparatus," US Patent 6,063,194, issued 16-May-2000; and "Pharmaceutical Product and Method of Making," Serial No. 09/095,616, filed 10 June 1998. Additional powder-handling devices, including a cone-shaped cloud chamber, are described in O'Mara et al., "Article Comprising a Diffuser with Flow," Serial No. 09/438,801, filed 12-Nov-1999.

All publications and references, including but not limited to patents and patent applications cited in this specification are herein incorporated by reference in their entirety as if each individual publication or reference were specifically and individually indicated to be incorporated by reference herein as being fully set forth. Any patent application to which this application claims priority is also incorporated by reference herein in its entirety in the manner described above for publications and references.

The following examples further illustrate the present invention, but of course, should not be construed as in any way limiting its scope.

Example 1: Two-layer Polymer Film of Ethylcellulose (EC) and HPMC:

The two-layer polymer film consists of a hydrophobic ethylcellulose (EC) film layer and a hydrophilic HPMC film layer. The first step: Cast EC dispersion plasticized with triacetin or other plasticizers over a Mylar film to make the ethylcellulose (EC) layer. Drying is conducted in a temperature/humidity-controlled chamber at 55°C and 35%RH. The second step: Cast HPMC solution over the resulting EC film, making the hydrophilic layer. Drying is conducted at 28°C and 45%RH. The two-layer film is then peeled off from the Mylar film.

Example 2: Polymer film Attached with Conductive Domains

Disperse carbon black into hydroxypropyl cellulose polymer solution to make a conductive polymer film. Disk-like film portions are punched out from the film. The conductive disks are then layered over an EC film (as in Example 1) and sealed by
5 ultrasonic welding. The EC film has high surface resistivity (targeted at $2.6\text{E}+12$ ohm/square at 20 %RH and $1.2\text{E}+12$ ohm/square at 30%RH, respectively).

While this invention has been described with an emphasis upon preferred
embodiments, it will be obvious to those of ordinary skill in the art that variations in the
10 preferred devices and methods may be used and that it is intended that the invention may
be practiced otherwise than as specifically described herein. Accordingly, this invention
includes all modifications encompassed within the spirit and scope of the invention as
defined by the claims that follow.